gracilis) var., N. circumsuta, Melosira Borreri, Hyalodiscus Californicus, Actinocyclus Barklyi, Navicula Yarrensis, N. Smithii, Surirella craticula (so called, = *Navicula sp.), Epithemia musculus.*

As this is a record of facts, while I have endeavoured to show their immediate bearing and connection, I have abstained from any wide speculation as to the past history of the Lower Yarra. I do not think that the depth of the silt is at all an accurate measure of the time that has elapsed since the arcas and oysters lived. Soundings made in Hobson's Bay by Mr. Moseley in 1867, 1869, 1871, and 1878, and by Captain Stanley in 1875, showed that over the western part of the Bay there had been in the eleven years a general deposit of 12 to 36 inches of silt. The area within a radius of a quarter of a mile from Williamstown Pier had, however, not shallowed at all in the period. With variations from an increase of *nil* to an increase of 36 inches in eleven years we have no grounds for a choice of rate of deposition, nor reason for striking the average. It is advisable, then, to postpone any extensive generalisations until other parts of the delta have yielded further evidence. It is to be hoped that opportunities will be seized as they occur of recording such evidence.

Art. XIV.—*On the Sound Organs of the Green Cicada.*

Cyclochila Australasiæ, Donovan sp.

By A. H. S. Lucas, M.A., B.Sc., F.G.S.

[Read 14th October, 1886.]

Of all insects the cicadas have perhaps for the longest period attracted the curious interest of men of all nations and on all the continents. It is then not a little singular that there should be any disagreement amongst zoologists as to the precise manner in which these assiduous musicians

produce their music. For many years Réaumur's explanation of the process, published in 1740, in his *Mémoires**, was generally received; but in 1872 Landois published a monograph on "Die Ton-und Stimm-Apparate der Insekten" in the *Zeitschrift für Wissenschaftliche Zoologie,* in which he advanced a novel theory on the subject. I have not been able to obtain access to the original paper, but Huxley† quotes Landois as contending that "the posterior thoracic stigmata are the vocal organs. These open into chambers, in the walls of which tense membranes are so disposed as to intensify the sound by their resonance." In this view clearly, then, the sound is a true *voice,* produced as in man by a modification of the tubes of the breathing apparatus.

This is a taking theory. Nor is it so easy for European naturalists, save on their travels, to verify or discredit it for themselves. Thus there is but one tiny British species, and that now only rarely to be found in the New Forest. The European forms cannot compare in size with some of our own, and with many exotic species. The life of the adult insect is a short one, and exotic specimens could not be taken to England to repeat their performances before a scientific jury. From the habits of the larvæ, the rearing of cicadas would be attended with great difficulty. Réaumur himself writes‡:—

"Heureusement que ces parties, les plus singulierès de l'extérieur de ces mouches, peuvent être bien vûes sur celles qui sont mortes; et que pour les étudier et les disséquer à l'aise il faudroit faire périr les cigales qu'on auroit vivantes; car je me suis trouvé engagé à l'ècrire leur histoire sans en avoir jamais entendu chanter une, et sans en avoir jamais possédé une en vie."

Anatomy certainly gave Réaumur the clue to the correct theory, but we need also to bring the rival theories to crucial tests by experiment in order to definitively determine between them.

I was much exercised, as every new comer must be, on listening to this noisy Victorian species for the first time in 1883. By dissection and a few simple experiments I made out what I conceived to be the *modus operandi,* and all my observations agree with the older theory of Réaumur,

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* Tome 5.

† *Anatomy Invertebrated Animals*, page 438.

‡ *Mémoires,* tome 5, page 149.

and do not confirm the newer theory of Landois. I read a few notes on the subject before the Field Naturalists' Club of Victoria soon after. In later seasons I have repeated and extended the experiments. As attention has been called to the subject lately by Professor Lloyd Morgan *, who from examination of the corresponding species at the Cape of Good Hope has also come to distrust Landois' explanation of the process, I have thought it well to put on record an account of our green cicada, in which the organs are conspicuous, and which can be obtained with the utmost freedom at midsummer.

As will be seen from the specimens and dissections, the organs are situated in the first two segments of the abdomen in the males, occupying a space about one-third of the entire bulk of the animal. This fact alone shows the importance of the structure to the insect in the struggle for existence.

By a comparison with the unmodified segments of the female we find that the sound apparatus of the male has been developed by a specialisation of the terga of the first abdominal and the sterna of the last thoracic and first abdominal segments, accompanied by a remarkable development of the muscles of the trunk of the same two segments, and a suppression of the muscles of the succeeding abdominal segment.

In the anterior membranous slope of the dorsal surface of the first abdominal segment, facing the thorax, a pair of elliptical, sclerous membranes are differentiated, one on each side. These are set obliquely to the long axis of the body, are convex backwards and upwards, and are strengthened with chitinous ridges running from the anterior and inner to the posterior and outer angle. These are the rattle-membranes, by the internal friction of which, of the ridges on each other when in rapid vibration, the sound is originated. These rattle-membranes are protected by a corresponding pair of stout plates which project forwards over them, from what is in the female insect a mere transverse ridge of the abdominal tergum.

The ventral modifications are no less remarkable. The confronting surfaces of the metathorax and abdomen, in close apposition in the female, diverge widely in the male,

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* *Nature*, Vol. 33, Feb. 18, 1886, p. 369

the greater portion of each becoming transformed into a pair of tense, delicate, translucent membranes, which constitute the inferior boundaries of air-spaces. The tension-membranes of the metathorax are the smaller, and look downwards and backwards; those of the first abdominal segment, much larger, look downwards and forwards. A chitinous ridge and band separate the two pairs transversely. In the ventral middle line a short, stout ridge connects inferior medial projections, a blunt spur from the metathorax, and a semi-circular plate from the abdominal segment, and serves for the linear attachment of the great abdominal muscles. Both pairs of these delicate membranes are likewise protected by two large chitinous plates, which arise externally to the legs in the metathorax, and are enormously larger than corresponding folds in the female. These plates quite cover in the white membranes.

A pair of huge muscles take their origin close together below, along the visceral aspect of the median ridge referred to, and with great antero-posterior extension proceed upwards and outwards, diverging as they rise, to terminate about a quarter of an inch below the rattle-membranes in broad, plate-like, rigid terminals. From these tendinous slips pass to the rattle-membranes.

Capacious air-spaces, which act as resonators, are formed by absorption or suppression of peri-visceral and muscular elements in the regions affected. The general boundaries of the air-space are—in front the muscles and viscera of the meso-thorax; below the two pairs of tension-membranes; behind the muscles and viscera of the hinder abdominal segments; and above the rattle-membranes. But this space is subdivided into successive resonators as follows:—(1) Antero-lateral recesses, bounded by the rattle-membranes above, the muscles and their terminal plates within, and the anterior tension-membranes below; (2) median recess between the diverging muscles; and (3) the vast drum-like cavities behind the muscles and above the great tension-membranes, excavated at the expense of the normal abdominal contents.

The *modus operandi* is apparently this. The muscles contract, and by their tendons set the rattle-membranes in a motion which is perfectly free. Vibratory motion would have been hindered or prevented altogether by a direct insertion of the massive muscles into the rattle-membrane. The vibrations of the membranes produced by the friction of the horny ridges is communicated to the air of the resona-

tors, probably in succession to the subdivisions in the order indicated, and the shrill chirp thus so strangely intensified.*

The experiments which lead me to assign these respective functions to the different organs are as follows :—

(1.) The sound was produced without diminution of volume in the living insect:

(a) When the wings were removed.

(b) In the abdomen, when the cephalo-thorax was removed.

(c) When the hard protecting plates, both upper and lower, were removed.

(2.) The sound could be produced, though with somewhat less loudness, by irritating or by artificially working the great muscles while fresh in the separated abdomen.

(3.) The sound was almost entirely lost on slitting the rattle-membranes in the otherwise unmutilated animal. The insect worked there as before, but the charm was broken, and its voice was lost.

(4.) Vibrations of all the white tension-membranes took place *without the sound*, but these always vibrated when the sound was given forth, those of the thorax with greater amplitude. The sound was not affected by even a large rent in the great tension-membranes of the abdomen. Thus these membranes serve probably to give greater freedom of motion to a larger volume of air in the resonators.

(5.) The corresponding segments of the abdomen in male and female insects are easily recognisable. In both sexes there are five segments, each of which carries a pair of stigmata on the under surface about midway between the middle line and the margin on either side.

The stigmata of the mesothorax are most prominent; they are provided each with a cover, consisting of a pair of valves, which close and open at irregular intervals, apparently at the will of the animal, like eyelids.

The stigmata of the metathorax can be seen also without any difficulty in situation exactly corresponding to their position in the mesothorax. A bristle can be passed through a stigma into the air-tube without passing into any of the

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* In a brief note " On the vocal organs of the Cicada," Proc. L.S.N.S.W., August, 1886, Mr. Haswell accepts Réaumur's theory. He gives no experiment, but adds the idea that the strips of which the great muscles are composed act independently or successively. The American authors, as Packard, are orthodox believers in the older view.

air-chambers of the sounding apparatus. I separated the abdomen, produced the skirr in it, and then passed a bristle through the metathoraic stigma for a distance of nearly half an inch along the tracheid.

(6.) There was no connection between the times of the rise and fall of the cover for the stigma of the mesothorax and the sounding of the rattle.

To work out the question fully we need, further—(1) to trace the development of the organs in the pupa, which is rather difficult to obtain; (2) to compare the adult organs of the Green Cicada with those of the other species of the family. I believe that a graduated series of forms might be obtained in which, as in the successive stages of growth of an individual, we might trace the gradual progression of these singular sound-organs, from simple beginnings to the highly elaborated apparatus of the *Cyclochila Australasiæ*.

EXPLANATION OF PLATE.

Fig. 1. *Cyclochila Australasiæ*. Male insect, natural size. (*a*) Stridulating organ of left side.

Fig. 2. Side view of same, enlarged. Both pairs of wings have been removed, and also the opercular or protecting plates. (*a*) Rattle-membrane or stridulating organ; (*b*) great tension membrane of abdominal segment; (*c*) tension membrane of metathorax.

Fig. 3. View of separated abdomen from before. (*a b*) As before; (*m*) great muscles; (*t*) tendinous slips of same; (*p*) opercular plates covering stridulating organs.

Fig. 4. View of great muscles from behind. (*b m*) As before.

Fig. 5. Internal view of abdomen divided in longitudinal median section, from the left. (*a b m*) As before; (*o*) plate-like terminal of right muscle.

I am indebted to my accomplished friend and colleague, Mr. Frank Goldstraw, for the drawings in this Plate.